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A REVIEW OF LITERATURE ON THE GEOLOGY OF SOUTH AMERICA.

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ARCHEOZOIC AND PROTEROZOIC (PRE-CAMBRIAN)

The pre-Cambrian of South America is mainly limited to three regions:

(a) Guiana, including portions of northern Brazil and southern Venezuela.

(b) The highlands of eastern and southern Brazil.

(c) Narrow strips in the Andes lying north of 40° S. latitude, together with similar strips running north and east from the main chain in northern Venezuela. These Andean strips may be of much later age, but they have been referred to the pre-Cambrian.

The first of these regions includes an area of more than 500,000 square miles of elevated broken land. It is separated from the Atlantic coast by a 10 to 70 mile wide strip of post-Tertiary sands and gravels, is (according to Crosby) bordered on the north and west for a distance of 800 miles by the Orinoco River, and to the south dips under Paleozoic and more recent sediments along a line which Derby draws approximately "from the mouth of the Amazonas, in latitude 1° N., to the confluence of the Rio Negra and Rio Brancho, between 1° and 2° S. latitude."[1]

The rocks of this region Crosby has grouped together in somewhat the following manner:

Pre-Cambrian

(4) ——— Semi-crystalline schists and marbles.

Great unconformity

(3) Montalban series. Gneisses and schists cut by coarse granite dikes. Garnets common.

(2) Huronian series. Quartz porphyry and felsite associated with various hornblende and slaty rocks showing distinct bedding.

(1) Laurentian series (?). Granite and some syenite.[2]

1. Crosby, W. O., Proc. Boston Soc. Nat. Hist., Vol. XX, 1881, p. 484.
2. Crosby, W. O., Loc. cit., p. 493.

No thicknesses are given and the value of the classification is perhaps questionable, but it appears to be the most complete of any thus far in print.

Concerning the semi-crystalline schists and marbles (No. 4 of the above section), Crosby says they "represent a horizon near, but below, the boundary line between the Eozoic and Paleozoic." And the granite (No. 1) "lies at the base of all the rocks of the colony (British Guiana) and coarse veins of it have pierced all the overlying formations including even the sandstone in one place."[3] This rock is identified as Laurentian in age but it either includes younger intrusives or is itself much younger, as the sandstone said to have been cut by it is identified as Triassic. At some places the granite is said to show a gneissic structure and again to pass over into distinct gneiss.

These old crystalline rocks are thought to have been above the sea in earliest Paleozoic time, but that they have not remained above throughout all the succeeding time is suggested by the great mass of Triassic sandstones capping the hills over 10,000 square miles of British Guiana.

The pre-Cambrian rocks of the highlands of eastern and southern Brazil cover a much larger area and, as in the former area, are in part covered by undetermined later formations. They extend over more than 30° of latitude and 25° of longitude. Here, as to the north, two great divisions of the rocks are represented. These consist of "two very distinct series, of which one, the most ancient, consists of crystalline rocks, including gneiss, gneiss-granite, and syenite, and the other more modern, of altered, but in general non-crystalline rocks consisting of quartzites, metamorphic schists and crystalline limestones."[4] The section is essentially the same as that given for the Guiana region and the same great unconformity is recognized. The transitional rocks above the unconformity are mainly quartzites and schists, with some argillite, crystalline limestone and bedded iron ores. The quartzite frequently passes over into ordinary sandstones, among which is the well-known flexible sandstone—itacolumite.

As an evidence of the age of the land-surface in this part of Brazil, Branner says that "the fine-grained gneiss in the vicinity of the city of Theophilo Ottoni, is so deeply weathered that one seldom sees a hard rock face."[5] The street and railroad cuts are made in the decomposed rock. At one place near the railroad station, the rock cut is 10 meters in depth and the schists stand as a perpendicular cliff, although so much decayed that one can thrust a knife into them anywhere.

3. Loc. cit., p. 493.
4. Derby, O. A., Proc. Amer. Phil. Soc., 1879, pp. 155-178, 251-258.
5. Proc. Wash. Acad. Sci., Vol. II, 1900, p. 187.

On the Pacific slope of the Andes from Patagonia northward the old formations show a similar three-fold division and are said to have essentially the same characteristics. It is probable, however, that these formations are of much later age.

PALEOZOIC.

The Lower Paleozoic Rocks. The lower Paleozoic formations of South America are not always recognizable and are perhaps wanting in some regions where later formations occur, but it is probable that a portion of the crystalline schists, quartzites and slates which have been referred to the pre-Cambrian are in reality early Paleozoic formations. In the Amazon region Derby says that the Silurian rests unconformably "on an extensive series of quartzites superior to"[6] the gneiss, but the age of this assemblage of rocks is not suggested. In this same region Katzer maps the Silurian as unconformable on a series of metamorphic rocks[7], which appear to be of pre-Cambrian age.

In Bolivia and northwestern Argentine occur outcrops of sandstones and quartzites in which a fauna of Upper Cambrian age (*Agnostus, Olenus, Conocoryphe* and *Ptychoparia*) has been collected.[8] The base of this series of rocks is not exposed and its thickness is unknown. In this same general region (Bolivia and Argentine) the Ordovician is represented by yellow argillaceous or quartzitic sandstones and black shales which are thought to represent the same horizon as the Orthoceras limestone (base of Ordovician) of the Baltic.[9] Among the fossils collected from this horizon are *Illaenus, Orthoceras* and *Eudoceras* from the sandstone, and four genera of graptolites from the black pyritic shales exposed along Rio Corauhuata at Culi, Bolivia.[10] DeLapparent says this same fauna also occurs near Lima, Peru; and again along the coast of Venezuela between Caracas and Puerto Cabello, the finding of Ordovician fossils, among which is *Calynimene senaria,*[11] indicates the presence of this system.

Silurian rocks are reported to occur along the coast of Chili but they are highly metamorphosed[12] and have not been well described. In southwestern Brazil, southern Peru and northwestern Argentine the Silurian rocks outcrop almost continuously

6. Derby, O. A., Amer. Jour. Sci., 3d ser., Vol. XIX, 1880, p. 324.
7. Katzer. Friederich, Grundzüge der Geologie des unteren Amazonasgebietes. 1903. (Leipzig), p. 216.
8. Kayser, E., Beiträge zur Kenntniss einiger palaeozoisher Faunen Südamerikas (Reviewed by Frech). Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie. Band II, 1898, p. 472.
9. DeLapparent, A., Treaté de Geologie, Tome III, p. 808.
10. Evans, J. W., Quart. Jour. Geol. Soc. London, Vol. LXII, 1906, p. 431.
11. Drevermann, Neues Jahrbuch, Band I, 1904, p. 91.
12. Forbes, David, Quart. Jour. Geol. Soc. London, Vol. XVII, 1860, p. 61.

over a region extending from northwest to southeast more than 700 miles and including an area of 80,000 to 100,000 square miles. These rocks form the mountain chain of the highest Andes, rising to a maximum elevation of 25,000 feet above sea-level.[13] In Peru they consist of blue to gray and black clay slates, shales and graywackes, with a subordinate amount of sandstone. East of La Paz the Silurian is thought to be fully developed and here Forbes estimated its thickness at 15,000 feet,[14] but it is quite probable that this includes also the Ordovician and a portion of the Cambrian.

Near Hancq in northwestern Argentine the Silurian is about 4,000 feet thick and consists of bluish gray to yellowish rough uneven-bedded limestone interstratified with marl, and all quite fossiliferous.[15] The Silurian strata of the Bolivia-Brazil-Argentine region are not very much folded but are faulted, tilted and often cut by intrusions of granite, porphyry, diorite, trap, etc., and in the vicinity of these masses the strata are altered into gneissic and schistose rocks whose sedimentary origin is only occasionally to be recognized.[16] Important veins carrying gold, silver, lead, tin, copper, zinc, nickel, etc., occur in the Silurian rocks and are thought to have been formed prior to the extrusion of the post-Paleozoic lavas.

In the Lower Amazon region Silurian strata outcrop on the Guiana side in a narrow strip (4± miles wide) along the southern margin of the metamorphic rocks, from the Rio Trombetas nearly to the Atlantic Ocean. On the river mentioned they have been studied to some extent and a considerable fauna collected (*Orthis, Lingulops, Tellinomya, Anodontopsis*).[17] Here they consist of about 1,000 feet of hard argillaceous and fine-grained micaceous sandstone, with some shale between the layers and about twenty feet of schists at the bottom, resting unconformably, at one place on felsite and at another on syenite.[18]

At the Morro do Cachorro the Silurian sandstones have a grayish, yellowish or reddish color, are often banded, and dip to the S. SW. at an angle of 5°. They frequently contain impressions similar to those recognized in the Medina of North America

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13. Forbes, David, Ibid., p. 53.

14. Forbes, David, Ibid., p. 61.

15. Bordenberger, W., Leitschrift der deutschen geologischen Gesellschaft, Band XLVIII, 1896, pp. 743–772.

16. Forbes, David, Loc. cit., p. 61.

17. Clarke, J. M., The Paleozoic Faunas of Pará, Brazil; Archivos do Museu Nacional do Rio de Janeiro, Vol. X, 1900, pp. 1–24.

18. Derby, O. A., Proc. Amer. Phil. Soc., Vol. XVIII, 1879, pp. 167–169.

under the name *Arthrophycus harlani* Con.[19] and hence may be the upper part of the Ordovician. Silurian strata are recognized by fossils to the north of the river only. Those called Silurian to the south are identified as such by their petrographic appearance and stratigraphic occurrence.

Devonian. The Devonian of South America is known in Brazil, Peru, Bolivia, Argentine and the Falkland Islands.

In Brazil strata referred to this system are found in the state of Pará on both sides of the Lower Amazon; in the province of Mato Grasso in central Brazil and the province of Paraná in southern Brazil.[20] In the Lower Amazon region it is best exposed on the north side of the valley where it forms a narrow belt along the border of the Silurian. O. A. Derby divided the Devonian of this region into three groups[21] as follows: The Maecurú, consisting of about 30 feet of massive coarse white or yellowish sandstone which is sometimes hard and sometimes a mere bank of sand. It contains an abundance of well-preserved fossils. This group rests on the Silurian, perhaps conformably, and is followed by the Erere group consisting principally of thin-bedded fine-grained micaceous sandstone with a subordinate amount of black shale. These sandstones are generally white in color but weather red, while the shale weathers to a whitish color. Near the base some cherty sandstone occurs. The whole group is quite fossiliferous and those forms occurring in the shale are different from those in the sandstone. Derby says there are thirteen distinct beds and the total thickness is about 200 feet. Above this lies the Curuá group, consisting, in the lower part, of about 300 feet of well-laminated almost slaty black shale, with concretionary beds containing the cone-in-cone structure and having a strong odor of petroleum. In the upper part the group consists of an equal amount (300 feet) of chocolate colored shale mottled with spots of a darker color and banded parallel to the bedding with various colored layers. This rock is mostly a clay mixed with much finely divided mica and sand. The lower part of these red-brown shales and the upper part of the black shales are abundantly marked with *Spirophyton.* This group is followed by about 50 feet of coarse sandstone of undetermined age and then follows (upper) Carboniferous rocks with distinctive fossils.

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19. Katzer, Friederich, Grundzüge der Geologie des unteren Amazonasgebietes, 1903, p. 216.

20. Thomas, Ivor, Zeitschr. d. deutsch. Geol. Ges., Vol. 57, 1905, p. 234.

21. Proc. Am. Phil. Soc. for 1879, pp. 169–171.

A more recent, although less detailed section of the Maecurú valley is given by Friedrich Katzer[22] as follows:

Carboniferous.
Unconformity.
Devonian.
6. Black shale.
5. Red micaceous sandstone. The upper fossil-bearing horizon.
4. Darker sandstone.
3. Hornstone.
2. Spirifer sandstone. The principal fossil-bearing horizon.
1. Thin-bedded sandstone interbedded with shale.
Silurian.

Mr. Schuchert makes the hornstone of the above section the dividing line between the lower and upper Devonian[23] of the lower Amazon and on the basis of fossils refers that below to the age of the Oriskany and that above to Hamilton. In this he follows Katzer. The Devonian of this region is frequently faulted, but only slightly folded and often cut by diabase dikes. In the province of Mato Grasso the horizon of the Devonian exposed is not known but it is probably that of the lower part of the Maecurú group, as indicated by the few fossils collected. The same horizon is reported from Paraná[24] where the deposits are principally brown and black shales.

The Devonian of Bolivia, east of Lake Titicaca, consists principally of yellowish to gray sandstones and black shales. Only in the strongly folded part of the Cordillera does the rock take on a graywacke character. The Devonian is easily distinguished from the underlying Silurian by its never failing mica content, and by its normal sedimentation from the overlying salt and gypsum-bearing red sandstones of the Cretaceous. The Devonian is overlain by Carboniferous only in the northern part of Bolivia.[25] These rocks are all highly fossiliferous and are thought to represent the Oriskany sandstone, the Onondaga limestone and the Hamilton beds of North America.[26]

In Argentine the Devonian is well exposed in the region of Rio del Jachal. On the east side of the river the system is 400 meters thick and consists of 200 meters of unfossiliferous shales, above which lies 200 meters of shales and graywackes with three fossiliferous horizons. To the west of the Jachal two other outcrops occur. Here the Devonian consists of 2,000 to 3,000 meters

22. Grundzüge der Geologie des Amazonasgiebetes, 1903 (Leipzig), p. 191.

23. Jour. Geol., Vol. XIV, 1906, p. 731.

24. Thomas, Ivor, loc. cit., p. 238.

25. Knod, Reinhold, Neues Jahrbuch für Mineralogie, Geologie, und Palaeontologie, Vol. 25 (Beilage Band), 1908, pp. 574, 575.

26. Steinmann, Gustav, Am. Nat., Vol. 25, p. 856.

of graywacke, sandstone, quartzite and shale with a subordinate amount of limestone.

In the Falkland Islands at Cerro del Fuerto the Devonian rests conformably on the Silurian and consists chiefly of micaceous red sandstones.[27]

The fauna of South America is closely related to that of North America. This is shown, especially, by the presence of such forms as *Chonetes coronatus* and *Tropidoleptus carinatus* in the lower Devonian, which occur later in the Hamilton of North America.

Carboniferous and Permian. The Carboniferous formations are apparently more restricted in South America than the Devonian, but occur in the same general regions.

The Lower Carboniferous (Mississippian) is made up, in large part, of non-fossiliferous sandstones. The Upper Carboniferous (Pennsylvanian) is largely marine and contains representatives of widely distributed brachiopods and gastropods. Fusulina limestones occur in Peru, Bolivia and Brazil.[28]

In the lower Amazon region Carboniferous strata (probably both Mississippian and Pennsylvanian) are well exposed. These beds seem to be unconformable on the older formations[29] but dip with them into the Amazon embayment. Along the Rio Tapajoz, north of Itaitúba in the province of Pará, the system is composed of green shales at the bottom which are followed above by coarse black shales with numerous concretions (septaria). These shales are succeeded by laminated green, white, and red arenaceous shales and sandstones and capped by more than 60 feet of limestone.[30]

In the provinces of Paraná and Santa Catharina, southern Brazil, the Carboniferous rests unconformably on the Devonian, or sometimes on the granite itself. In the lower part is a coarse conglomerate, but from this upward the succession is continuous through the Trias without any great unconformities. I. C. White includes the Carboniferous, Permian and Triassic in the Santa Catharina system.[31] His classification of the former two is as follows:

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27. Thomas, Ivor, loc. cit., p. 244.

28. Steinman, Gustav, Amer. Nat. ,Vol. XXV, 1891, p. 856.

29. Kayser, Emanuel, Lehrbuch der Geologie, 3d Ed., Vol. II, 1908, p. 238.

30. Hartt, C. F., Bull. Cornell Univ., Vol. I, No. 1, 1874, p. 29.

31. Commissao de Estudos das Minas de Carvao de Pedra do Brazil. Relatorio Final, 1908, p. 33.

Santa Catharina System	Sao Bento series (Triassic)	Sandstones, shale and eruptives	900 m.	
	Passa Dois series (Permian)	Rocinha limestone	3 m.	223 m.
		Estrada Nova, gray and variegated shales with cherty concretions and sandy beds	150 m.	
		Iraty black shale (contains *Mesosaurus* and *Stereosternum*)	70 m.	
	Tubarao series (Permo-Carboniferous)	Palermo shales	90 m.	180 m.
		Rio Bonito shales and sandstones (Coal Measures and Glossopteris flora)	158 m.	
		Orleans conglomerate	5 m.	
		—— yellow sandstones and shales to granite floor	27 m.	

The lower member of the Carboniferous consists of sandstones and shales resting on the granite. Overlying these is the Orleans conglomerate which is made up of "boulders of granite, quartzite and other hard rocks, some of which are 20 to 25 cm. in diameter" imbedded in clay. This conglomeratic character is common throughout southern Brazil. At "several localities near Rio Negro, 10 kilometers from any outcrop of granite," it contains "granite boulders in vast numbers up to 3 meters in diameter, all imbedded in a fine and apparently unstratified gray muddy sediment."[32] White thinks this deposit corresponds in age to the Dwyka conglomerate (Permian) of South Africa, to which it bears much resemblance, and that it is of glacial origin.

The Rio Bonito beds (Coal Measures) consist of partly consolidated yellowish and grayish white sandstones interbedded with gray shales and several beds of coal. The coals of Brazil are all poor. In the lower part of the Rio Bonito beds is the Bonito coal, locally making up most of the formation. Its thickness frequently runs as high as 2.5 and even 3.22 meters and is quite persistent in the Minas region, but it contains much shale and the coal is of poor quality.

Above the Bonito coal bed is a horizon containing many plant remains, among which the abundant fossils belong to the genera Sigillaria and Glossopteris.[33] The only other important coal bed

32. White, I. C., loc. cit., p. 51.
33. White, I. C., loc. cit., p. 79.

is the Barro Branco bed, much higher in the formation. It also consists of seams of coal separated by thin layers of shale.

The Palermo shales lie conformably (?) on the Rio Bonito beds and are made up of soft gray and red shales.

Since the Permian is thought to be conformable, or essentially so, on the Carboniferous, the shales, limestones and cherts of the Passa Dois series may be considered here.

The Iraty black shale, which is a widely persistent formation, is distinguished by its Reptilian remains and by the ever present odor of petroleum. It contains nearly 20% of volatile matter and 9% of carbon.

The Estrado Nova beds consist of gray and variegated shales with some sandstones.

The Rocinha limestone is the top of the Permian and forms a persistent dividing line between it and the Triassic.

In northwestern Argentine there is a series of sandstones and shales with some coal which are at least in part Carboniferous. They lie unconformably on the older Paleozoic rocks (Devonian?) and are overlain conformably by the Triassic as in southern Brazil The Glossopteris flora also occurs here.[34]

Rocks of (Upper and Lower) Carboniferous age are found in Bolivia in the vicinity of La Paz and north of Lake Titicaca. The system is made up of red sandstones, red and green shales, and some limestone. Some layers have a rich fauna which was at least locally of marine Pennsylvanian age.[35] The brown and red sandstones and conglomerates belonging to the Permian of Peru carry a considerable amount of copper which is thought to have been an original deposit. Salt and gypsum beds are also abundant.[36]

Strata carrying the Glossopteris flora occur in the Falkland Islands.

MESOZOIC.

Triassic and Jurassic. The Permian, Triassic and Jurassic of South America are very closely related and sometimes inseparable. Most of the continent was above sea-level throughout these periods, but probable land formations of this age are known at several localities in Brazil, while marine Triassic and Jurassic occur in the Cordilleras between 5° and 35° south latitude.[37]

In southern Brazil where the Triassic comes in contact with the Permian, the former consists of massive red sandstones which rest unconformably on the Rochina limestone (Permian) but the extent of this unconformity is unknown.

34. Kayser, E., loc. cit., p. 306.
35. Forbes, David, Quart. Jour. Geol. Soc. London, Vol. XVII, 1860, pp. 48–51.
36. Forbes, David, loc. cit. pp. 38–45.
37. Steinman, Gustav, Am. Nat., Vol. 25, 1891, p. 857.

The following section gives the general relations and more important subdivisions of the Triassic of Brazil:

Santa[38] Catharina System	Sao Bento series (Triassic)	Serra Geral eruptives	600 m.
		Sao Bento sandstones, cliffs of red gray and cream colored sandstones	200 m.
		Rio do Rasto red beds with fossil Reptiles and fossil trees	100 m.
			900 m.
	Passa Dois series (Permian)		223 m.
	Tubarao series (Permo-Carboniferous)		180 m.

The Rio do Rasto beds are composed of loosely consolidated red sands and conglomerates, while the Sao Bento beds consist of massive red, gray, and cream-colored sandstones which are sometimes conglomeratic and "often baked and vitrified by contact with the great sills of diabase which are so frequently intercalated between the massive layers as well as piled on top of the same.[39] The lower part of these beds (Sao Bento) are mostly red sandstone flags and the whole is apparently unfossiliferous. The hard vitrified rocks of the upper part of the series frequently form walls, towers, and buttes near the summits of the elevated peaks. The top of the section is made up of a great series of lava flows and the beds beneath are affected by numerous dikes and intrusive sheets.

The coal-bearing strata of southern Brazil is late Paleozoic, while that of Argentine and the Chilian Cordilleras belongs to the Rhaetic group and is partly covered by conformable marine deposits of lower Lias.[40]

The Triassic fossils of the Cordilleran region are of the same type as those found in California and western Canada, the leading fossil being *Pseudomonotis semicircularis* (?) Gratt.

Nearly all horizons of the Jurassic have been found to be fossiliferous and "the rich collections made in different parts of the Argentinian, Chilian and Peruvian Cordilleras have enabled us to determine that the succession of marine organic life during this period was quite the same on the Pacific slope as in Europe and East India, and there have existed very intimate faunistic relations between these regions."[41]

38. White, I. C., Commissao de Estudos das Minas de Carvao de Pedra do Brazil. Relatio Final, 1908, p. 33.

39. White, I. C., loc. cit., p. 211.

40. Steinmann, Gustav, loc. cit., p. 857.

41. Steinmann, Gustav, loc. cit. p. 857.

Cretaceous. The Cretaceous deposits are wide-spread in South America and represent a notable encroachment of the sea upon the continent. "Marine Cretaceous fossils are found in nearly all parts of the Cordillera from South Patagonia to East Venezuela" and a rich marine fauna has also been discovered in the Cretaceous formations of east Brazil.[42]

"Certain of the characteristic Lower Cretaceous fossils of the North reappear in the South. The famous genus *Aucella*, widely distributed on the slopes of the North Pacific, has been recently mentioned by N. Ritin from Mexico; by White from Brazil; and I (Steinmann) know it also from the environs of Lima associated with Ammonites of the Neocomian of Europe."[43]

The undoubted marine deposits of the central part of South America disappear to the north and the south and are replaced by sandy deposits without marine fossils. "Probably a great part of the red sandstone formations which occur in Brazil, Venezuela, Bolivia, and in the north of the Argentine Republic, take the same place relative to the marine sediments as do the Atlantosaurus beds, the Trinity and Tuscaloosa formations in North America."[44]

The Ammonite-bearing beds of the Lower Cretaceous in Patagonia,[45] Peru, Venezuela[46] and Columbia[47], have been worked out in detail. Gerhardt refers these beds to the European horizons, Neocom (?), Barrémien, Aptien, and Albien. The beds consist of dark blue limestone interbedded with quartzite, white and red sandstones. In Patagonia these beds have a rather limited distribution and are overlain unconformably (?) by the Dinosaur beds.[48] These latter consist of red sandstones, conglomerates, with clays, marls and volcanic tuffs.

On the Pacific coast of south Chili glauconitic sandstones are found which contain a rich fauna of the uppermost Cretaceous. This is especially shown on the Island of Quiriquina. "Besides many Ammonites and Baculites, partly identical with those from south India, this fauna is characterized by the abundance of Gastropods of Tertiary type. The Cretaceous beds are covered conformably by a lignitic formation whose fauna does not contain the Cretaceous fossils; but startigraphically both formations are

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42. Steinmann, Gustav, loc. cit., p. 858.
43. Steinmann, Gustav, loc. cit., p. 858.
44. Steinmann, Gustav, loc. cit., p. 858.
45. Faru, Francois, Neues Jahrbuch für Mineralogie, Geologie, und Palaeontologie, Vol. XXV (Beilage Band), 1908, pp. 601–647.
46. Gerhardt, K. Neues Jahrbuch für Mineralogie, Geologie, und Palaeontologie, Vol. XI (Beilage Band), 1897–8, pp. 65–117.
47. Gerhardt, K., loc. cit., pp. 118–208.
48. Roth, Santiago, Neues Jahrbuch für Mineralogie, Geologie, und Palaeontologie, Vol. XXVI (Beilage Band), 1908, pp. 94–118.

intimately united."[49] (Compare this with the Chico-Tejon of northern California.) On the western side of the border of Chili and Peru, where the marine deposits of these formations predominate, only a very small part of the rocks are formed by limestones, clay slates, or sandstones. These appear, however, to be "interlaid between stratified masses of porphyritic, melaphyric and andesitic material, the entire thickness of which strata reaches several thousand meters."[50]

In the lower Amazon region the Cretaceous (?) rests unconformably on the Carboniferous. The Cretaceous consists of yellow and white clays with red iron stone and some impure limestone. The fauna of these beds shows a remarkably Tertiary aspect. It consists, for the most part, of Gastropods, Pelecypods, some Bryozoans, Corals and Echinoderms, as well as some probable Reptilian remains.

The plateau region of southern Pará is mostly covered by clay shales interstratified with red sandstones. The age of these rocks is believed to be middle and older Cretaceous, and perhaps in part even Triassic[51] or Permian.

CENOZOIC.

Tertiary. The Tertiary deposits of South America occur principally along the coastal margin especially of Brazil, Argentine, Chili and Peru. Also in the Amazon basin these beds cover a large area,[52] and again in southern Argentine the same is true.

In eastern Brazil the Tertiary strata consist of slightly consolidated sands and clays which are undisturbed and overlie the Cretaceous unconformably.[53] Fossiliferous Tertiary beds (Upper Miocene) occur in the vicinity of Coquimbo, Chili.[54] These Chilian Tertiary shell beds, however, are found but sparingly in Peru.[55] The Tertiary beds of southern Patagonia vary from æolian, swamp, and lacustrine deposits to sediments carrying a marine fauna, and these are often interbedded with each other. The maximum thickness is about 1500 feet.[56] Tertiary lava flows and intrusions of igneous rock are common throughout the Andes[57] and are not rare even in Patagonia.

49. Steinmann, Gustav, loc. cit., p. 859.

50. Steinmann, Gustav, loc. cit., p. 859.

51. Katzer, Friedrich, Grundzüge der Geologie des unteren Amazonasgebietes, 1903, pp. 131–139.

52. Berghaus, Physikalischer Atlas, No. 14.

53. Hartt, C. F., Geol. and Phys. Geog. of Brazil, 1870, p. 557.

54. De Lapparent, A., Traité de Geologie, Vol. III, 1906, p. 1621.

55. Forbes, David, loc. cit., p. 9.

56. Hatcher, J. B., Am. Jour. Sci., 4th Ser., Vol. XI, 1900, p. 99.

57. Forbes, David, loc. cit., p. 12.

The deposits of borax, saltpetre, etc., in the Atacama desert and vicinity are of post-Tertiary age and are thought to have been formed by the deposition of the salts, contained in an inclosed portion of the sea, as the water evaporated.

Quaternary. Glacial drift (Pleistocene) occurs from Terra del Fuego northward at least to 41° S. latitude, while alpine glaciation occurs as far north as 9° S. latitude. "Besides the true glacial deposits and the æolian formations of loess and loam, there exists in South America, especially on the high plateau of Bolivia, lake deposits of great extent."[58]

Terraces and tuff deposits, analogous to those of the Great Basin region of North America, are well developed. Over the high lands of central Brazil and in Paraguay, river gravels and silts, similar to those of the Columbia formation, are also well developed, while the low plains and swamps are covered by alluvium.[59]

58. Steinmann, Gustav, loc. cit., p. 860.

59. Evans, J. W., Quart.,Jour. Geol. Soc. London, Vol. L. 1894, pp. 98, 99.

Chicago, 1909.